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A review of polymer composite materials in bulletproof vest to defense sector

Olivia T. Cahayaputri*
Republic of Indonesia Defense University,
INDONESIA

Riri Murniati
Republic of Indonesia Defense University,
INDONESIA

Sovian Aritonang
Republic of Indonesia Defense University,
INDONESIA

Aditya Tri Oktaviana
Republic of Indonesia Defense University,
INDONESIA

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Abstract

Personal protection, especially in the context of military protection and security, became a major focus in the development of bulletproof vests. Polymer composite materials offer a wide range of advantages in terms of strength, density, and ability to reduce the kinetic energy of projectiles, making them an attractive choice for such protection applications. This study examines the different types of polymers and composite technologies used in the manufacture of bulletproof vests. This study examines the use of polymer composite materials in the manufacture of bulletproof vests used in the defense sector. We evaluate the mechanical, thermal, and ballistic properties of these materials and investigate the design approaches applied to improve the performance of these protectors. The research proved that the composite was efficient enough to be used as a bulletproof vest material because it was light, flexible and strong.

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INTRODUCTION

Composite materials are widely used in industries such as automotive, aerospace, marine and infrastructure. Composite materials have also been widely used for military applications (Mallick, 2008). Indonesia always imports the necessary vests from other countries such as France, USA, Holland etc., but the materials of the vests are related to the country's defense and security system and the prices are so high that they are not accounted for. Materials science continues to evolve, including bulletproof vests (Fujiani, 2006).

This body armor is often used by the military to avoid bullet attacks. Several studies on composite materials have been carried out. The fibers used in composting include natural fibers and synthetic fibers. The advantage of this fiber is that it is renewable and readily available. Kevlar is found in aramid synthetic fibers. The principle of operation of bulletproof vests is to reduce kinetic energy as much as possible. The maximum restraint limit should not exceed 4.4 cm (44mm) so as not to endanger life safety. This vest protects the wearer by stopping projectile velocity. The bullet stopped before entering the human body. When the vest resists bullet penetration, it reduces bullet

***Corresponding Author:**
Olivia T. Cahayaputri, Republic of Indonesia Defense University, Indonesia, Email: oliviatcp27@gmail.com

thrust by distributing the momentum of the throughout the body. The user still feels the bullet's kinetic energy, which can cause very serious bruising, swelling, or internal damage (Dan, 2011)

Current Kevlar body armor can only withstand the penetrating stresses caused by projectiles, so the impact energy is still conducted into the body, causing significant damage to the body. Composites are widely used in industry. The mechanical properties of plant fiber reinforced composites increase in proportion to the increase in fiber weight fraction (Azhari, 2017).

METHOD

Various research methods were experimentally carried out, starting with a literature survey. Each study used a different material for material usage. Types of fibers used in the form of carbon fibres, polyester fibres, long fibers from oil palm empty fruit bundles, and pineapple leaf fibres. This study combines empirical data, quantitative analysis, and qualitative assessments to provide a comprehensive understanding of the use of polymer composite materials in the manufacture of bulletproof vests for defense sector purposes.

RESULTS AND DISCUSSION

Some studies have been done to analyze the mechanical properties of the material and others up to the ballistic testing stage as a material for body armor.

Tjokorda and Daud Simon studied an economical ballistic suit made from polymer composites reinforced with silicon carbide particles and carbon fibers. The research method uses experimental research methods and adds variations of material thickness 20mm and diameter 110.5mm. The variable investigated was the independent variable of carbon fiber shape with variations of 3.5%, 4.5%, 5.5%, and 6.5% using 38 revolver pistols. Carbon fiber makes the skin itchy, so a mixture of silicon carbide and polyester resin is necessary. Then add the catalyst, put it in a vacuum chamber, do a combustion test, and put it on the market. In this result, the material fails when the fiber variation is less than 5.5%, and the material does not crack when it exceeds 5.5%. The nature of the change in the 5.5% fiber reinforcement is fiber sag. The firing range in this study was 10m, proving that the carbon fiber panels can achieve his NIJ Level II standards. The best variation of carbon fiber is 6.5%. Macrophotography observations were performed at Micro Photo Lab in Jimbaran, Bali (Daud & Tjokorda, 2010).

Mardiyati told the Defense and Security Innovation Journal about polymer composites as bulletproof materials, including the term polymer composites. In his opinion, a composite material is a structural material consisting of two or more materials that are insoluble in each other and bonded at a macroscopic level. Composites are multiphase systems of matrix and reinforcement materials. Polymers commonly used in military applications such as he do not interfere with matrix activity. As well as indentations for breathing. Currently, when using ballistic helmets, the armies of European countries use lightweight composite materials with a high level of ballistic protection and communication equipment. Military land vehicles made from fiber-reinforced composites can reduce vehicle weight and fuel efficiency. The use of composite materials in military applications has proven superior to metallic materials, especially in increasing the mobility of defense personnel (Mardiyati, 2018).

Zubaidi, Moekarto M, and Santoso M conducted research on the production of bulletproof vests using polyester fibers as a base material to improve on previous work on hemp fiber composites. It is a method of knitting polyester fiber and bundling 10 panels and sewing them horizontally at 10cm intervals. For impact testing, panels are made with 8 to 20 layers to determine their ability to stop bullets. Shooting tests were conducted at his two locations, Sulaiman Air Force Base and PT PINDAD shooting range in Bandung, at a distance of 5m where he used a P39 pistol.In the experimental results of this study, the higher the level , making it harder to hold the ball. Panel thickness is one of the most important factors that determine comfort. The thinner the eating plate, the better, as it affects the flexibility of the vest.In experiments after firing a bullet, the shape did not change much, but the penetration was quite deep. This vest meets the requirements of level II with the characteristics of good flexibility and comfortable handling. Panel weight, panel thickness, and design aspects should be evaluated when selecting materials (Zubaidi, Moekarto, & Santoso, 2009)

Muhammad Anhar Pulungan and Sutikno studied the effect of thickness on the impact energy absorption of hgm epoxy and carbon fiber composite bulletproof vests. The research methodology uses simulations with FEA software according to his NIJ Type III A test standard using an 8.1 g ball. The result of modeling a bulletproof vest using composite materials, with thicknesses between 1 and 20 mm in multiples of 5 mm. The results showed that a vest thickness of 1 mm absorbed bullet energy better than his HGM position in the middle. The thicker the vest, the lower the penetration of the projectile. From this, we can conclude that the combination of carbon fiber and HGM can reduce bulletproof vest penetration. Because HGM has strong properties and good stiffness (Pulungan & Sutikno, 2017).

Komang Astanawidi et al conducted his 2020 study on ballistic test analysis of bulletproof vest products using carbon fiber reinforced polyester composites, hemp and cotton. Several reinforcing fibers were used as laminates in this study, including carbon fiber, cotton fiber and polyester hemp fiber type 157. At 15 meters away is a standard test fire level III A, analyzed using SEM (Scanning Electron Microscope) photography. Shooting tests were conducted at the ARHANUD Education Center and SEM tests were conducted at the Brajiwaya University Laboratory. The use of fibers in this study used carbon fibre, cotton and hemp, with four of his samples measuring 30cm x 25cm. The first test used 5 layers with a thickness of 5 mm and a weight of 393 g. The second test uses 7 layers, 7.5mm thickness and 560g weight. The third test used 9 layers with a thickness of 10 mm and a weight of 820 g. The final test uses 8 layers with a thickness of 15mm and a weight of 1103g. In summary, adding hemp fiber slows the bullet down. SEM photo results show that the fibers are irregular due to penetration after the combustion test. The lining has gaps between the fibers and the matrix that reduce the performance of the vest (Widi et al, 2020).

The analysis of the mechanical properties of ballistic materials by adding long fiber-reinforced empty fruit bundles from oil palm was studied by Riza et al. as shown in Figure 1.

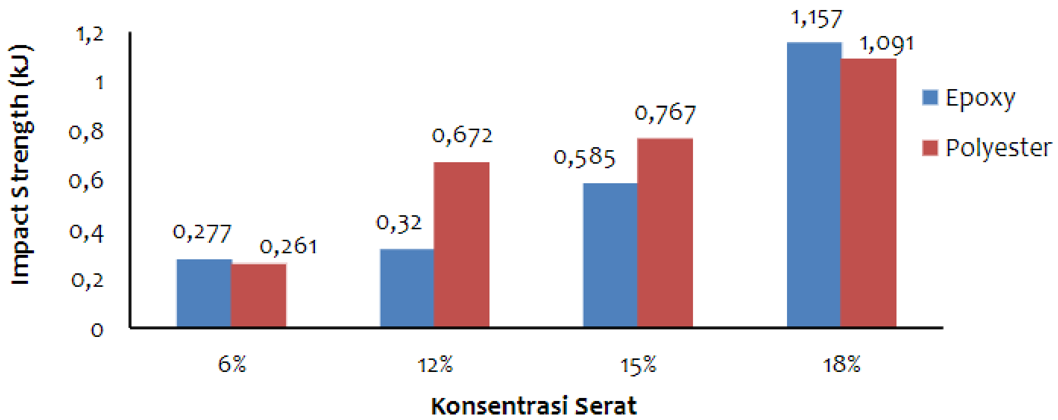

Figure 1. Impact strength of biocomposites
Source (Riza et al, 2022)

The mechanical properties or tensile strength of fibers are tested, i.e. the maximum stress a material can withstand when an object is stretched. Next, we make a heat-treated biocomposite. Additionally, biocomposites are tested to measure their durability and determine their strength. When testing the mechanical properties of biocomposites with impact resistance, the impact value increases as the concentration value increases. In the data, a fiber concentration value of 18% gives an epoxy value of 1157 kJ. The impact value is affected by the concentration value. This indicates that fiber addition can affect the impact strength of the material. When conducting ballistic tests, there are samples that penetrate projectiles and those that do not. The high fiber content allows the samples to be bulletproof. This study explains that fibers are the main component of composites because they can withstand most of the forces acting on them. The matrix protects the fibers and binds them together for proper functioning. The result of this study is a biocomposite with fiber added after obtaining the $Ca(OH)2$ mixture, and the mechanical properties of the fiber are sufficient

to be used as a bulletproof material. This is because biocomposites can absorb the force and energy emitted by a bullet (Riza et al, 2022).

Galindra Mutiara, Boy Rollastin, and Juanda conducted a study on experimental investigation of pineapple leaf fiber-reinforced composites in ballistic testing. This study uses experimental methods. Beginning with a literature review on specimen mold manufacturing and composite specimen shooting/ballistic testing, the final step is analysis. The test standard uses the NIJ Type III A standard for ammunition testing. The pattern print size is 15x15x2cm3 and the thickness is different from 10mm, 15mm and 20mm. Shooting tests were conducted at the MAKOSAT BRIMOB, KEP shooting range. Limited to bunkers. The weapon used was a Glock17 with a range of 25m, and the shooting test was performed three times. Any - Any thickness is a semi-transparent sphere. The manufacture of this vest is said to have failed due to the inability of the projectile to penetrate it in terms of penetration. Several factors failed to hold the projectile during the process of mixing HGM with pineapple fibers, resulting in incomplete samples or containing air bubbles and voids. External factors are shot angle, bullet shape, and temperature. Figure 2 shows the test shot bullet results can penetrate the sample. The thicker the sample, the less damage produce (Rahmatullah, Rollastin, & Juanda, 2021).

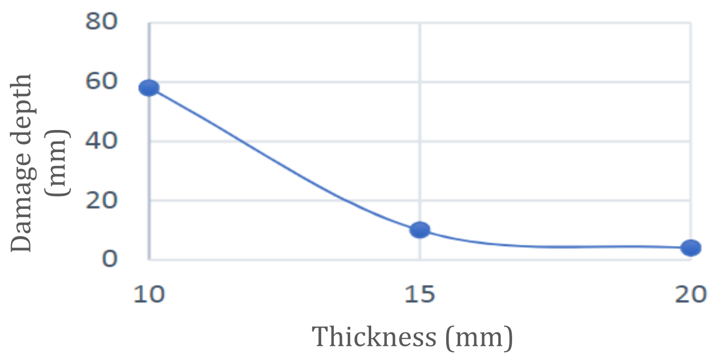

Figure 2. Graph of Test Results
Source (Rahmatullah, Rollastin, & Juanda, 2021)

Luk Lu Atun Nisa and colleagues investigated the potential for developing composite materials reinforced with natural materials for use as bulletproof vests. In this diary, the author re- explains the diary he read and creates a new diary. The findings and discussions in this journal are in the form of composite materials in the form of carbon fibres, hemp and cotton, pineapple leaf fibers, water hyacinth bark, bark, banana trees, and Sansiviera cylindrica using a variety of methods. I'm here. The authors said that natural fibers can be used as composite reinforcement It has been used as body armor and has been investigated in previous studies with success, but some studies have been unsuccessful and require evaluation. Also, the research focuses only on the mechanical properties of the material, i.e. impact and tensile tests (Nisa & Manawan, 2022).

CONCLUSION

Many studies reviewed show that composites are strong, lightweight and flexible, making them efficient enough to be used as materials for body armor. It's done behind the scenes. However, some studies are not all successful in ballistic tests and require evaluation. Further research is needed as the limitations of this study are strength and impact tests.

AUTHOR CONTRIBUTIONS

Each author of this article played an important role in the process of method conceptualization, simulation, and article writing

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